Lighting Metrics and Human Factors in Lighting

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Lighting Metrics

Sponsor:

Environmental Protection Agency





Lighting Metrics

- To maximize the acceptance of energy-efficient lighting systems, the LRC develops new lighting metrics (LMs).
 - Quantity: how much light a system will produce
 - Quality: how well the light will meet the needs
- Publishes LMs on LRC's website.
- LMs will allow users to compare lighting products more easily and choose the best.
- LMs will assist government regulators and lighting organizations in developing standards.





Lighting Metrics

- Unified photometry
- System efficacy
- LED life
- Temporal performance
- Circadian photometry
- Light pollution
- Color appearance





Unified photometry

- Photopic lumen is for foveal vision (daytime)
- Both Rods and Cones acting together are very important for night-time tasks such as driving
- Mesopic photometry is required to bridge the gap between the scotopic and photopic luminous efficiency functions

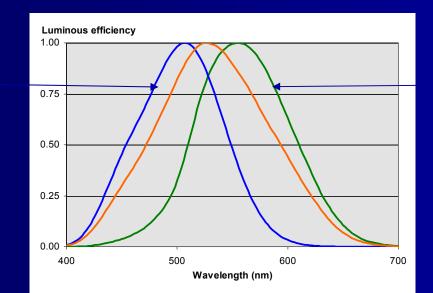




X, the bridge

- X is a coefficient to provide the proportion of photopic luminous efficiency for a given mesopic light level.
- At photopic levels, X = 1; at scotopic levels, X = 0

•
$$V_{\text{mes}} = (x)V_{10}(\lambda) + (1-x)V'(\lambda)$$



 $V_{10}(\lambda)$





Light source efficacies (lm/W) for photopic, mesopic (off-axis) and scotopic conditions, and percentage relative to HPS

Light source	Photopic V(λ)	Mesopic (0.3 cd/m ²)	Mesopic (0.1 cd/m ²)	Mesopic (0.03 cd/m ²)	Scotopic V'(λ)
HPS	120	108	87	81	77
	(100%)	(100%)	(100%)	(100%)	(100%)
MH	95	120	139	151	157
	(80%)	(111%)	(150%)	(186%)	(203%)
INC	15	17	19	20	20
	(12%)	(16%)	(20%)	(23%)	(26%)
FL35	80	84	101	108	111
	(67%)	(78%)	(109%)	(126%)	(144%)
FL75	58	78	109	120	132
	(48%)	(72%)	(118%)	(138%)	(171%)
LPS	180	136	89	58	41
	(150%)	(126%)	(102%)	(72%)	(54%)

Demonstration

Objectives:

- Demonstrate how to increase energy efficiency of street lighting through Unified Photometry.
- Demonstrate how mesopically-enriched fluorescent lamp systems can increase energy efficiency and lighting quality from conventional high-pressure lamp systems.





Advantages of fluorescent systems over HPS systems

- Lower illuminance and therefore lower energy consumption and less contribution to sky glow.
- Less glaring
- Higher uniformity
- Better color rendering
- Better sense of safety and security





Conventional HPS street lighting







New street lighting







Human Factors in Lighting





Human Factors in Lighting

- The impact of spectral power distribution on the achromatic visual task performance (SPD study)
- Perceived brightness management (Sparkle study)
- Lighting quality and office work (LightRight study)





SPD Study

Sponsors:

Department of Energy GE Lighting



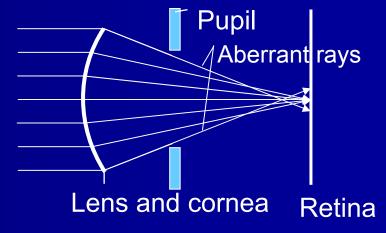


Background

Berman claimed a scotopically enhanced light source could reduce illuminance without impairing achromatic visual performance.

Why?

- Scotopically-enhanced light spectrum leads to smaller pupil size at the same luminance.
- Smaller pupil sizes mean better retinal image quality.
- Smaller pupils lead to a greater depth of field and reduce aberration.





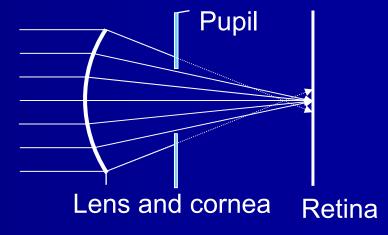


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Evidence

For: Berman, Fein, Jewett and Ashford, 1993 and 1994 Against: Smith and Rea(1979), Veitch and McColl (1995)

Why the difference?

- Threshold vs. suprathreshold tasks at threshold everything matters
- Magnitude of changes in pupil size the bigger the change the more likely that scotopically-enhanced light will have an effect





Questions

- How changes in pupil size affect supra-threshold task performance.
- Whether people notice and like the improved retinal image quality caused by smaller pupil sizes.

...under practical lighting conditions.





Experimental Conditions



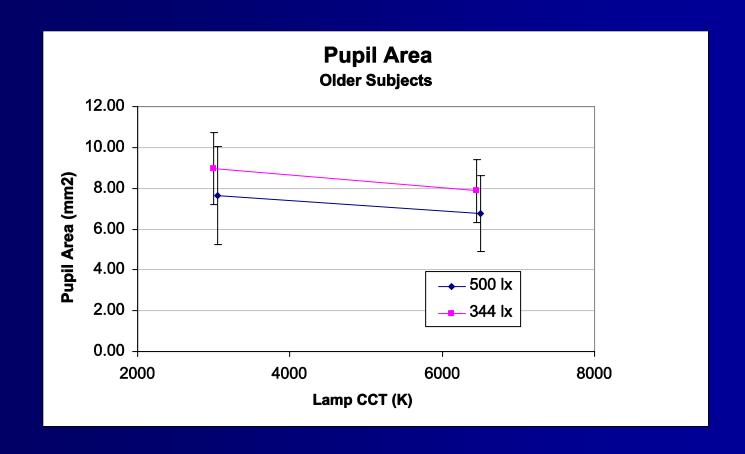
	Variables	Conditions	#
Lighting SPD		3000K (CRI: 78, S/P: 1.3) 6500K (CRI: 72, S/P: 2.1)	
	Illuminance	500, 344	2
Task	Landolt ring gap size (min arc)	1.5, 2.0, 2.5, 3.0, 3.5, 5.0, 8.0 and 14.0	8









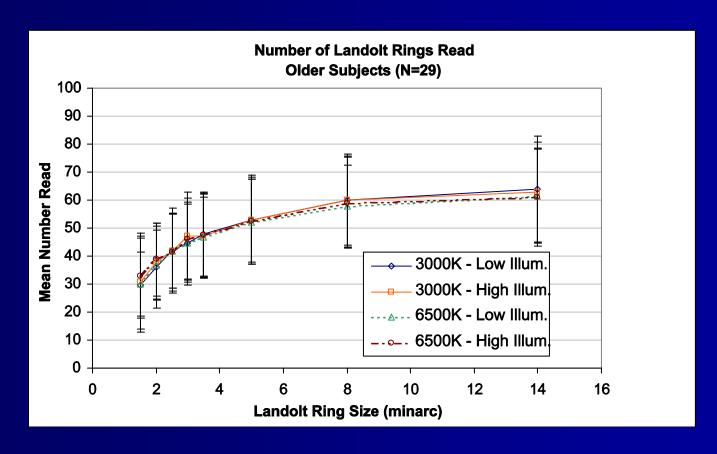






Results: Number of C-rings read









Conclusion (1)

- Both the illuminance and spectral power distribution of the light reaching the eye influence the pupil size.
- The change in pupil size does not affect task performance for a wide range of task difficulty.
- The factors determining task performance are the gap size in the Landolt ring and, to a much lesser extent, the task illuminance.





Conclusion (2)

- The 6,500 K light source is perceived by older people to make the performance of the task at large gap sizes less difficult than the 3,000 K light source, but not at small gap sizes.
- There is some indication that the 6,500 K lighting is perceived as brighter than the 3,000 K lighting, at the same illuminance.





Sparkle Study

Sponsor:

Connecticut Light and Power





VIP Lighting

Visibility, Impression, and Productivity

Provide lighting technologies such as:

- How to increase brightness perception in your office
- How to increase sales in your shop
- How to increase security of your municipality





Recipe for brightness: Sparkle elements

- To maximize acceptance of energy efficient lighting such as low ambient lighting and load shed dimming, recipes for brightness work.
- Recipes for brightness:
 - Sparkle elements
 - High CCT lamps
 - Wall washers and sconces





Sparkle increases perceived brightness





Before After





Objectives

Demonstrate how to reduce the lighting energy consumption in an open-plan office by 30% without reducing occupants' satisfaction or productivity, by using low-cost measures suitable for retrofit.











Schedule of sparkle study

Month	1-South	3-Central	2-North
1-6	As is	As is	As is
7-12	Half 3,500 K 3 lamp Half 6,500 K 3 lamp	Task light 3,500 K 2 lamp	Task light 6,500 K 2 lamp
13-18	Half 6,500 K 3 lamp Half 3,500 K 3 lamp	Task light 3,500 K 2 lamp Sparkle	Task light 6,500 K 2 lamp Sparkle



Applications of sparkle technique

- Indirect/direct pendant luminaire
- Street lighting luminaire







LightRight Study

Sponsor:

LightRight Consortium





Outline

- Study Objective: To identify the effects of best practice office lighting design on task performance, feelings and well-being over a working day
- 200 subjects participated in the experiment.
- Each subject worked on performance tests for 6 hours and answered questionnaires.





Lighting conditions

Installation 1: Base case

- Regular array of three-lamp parabolic luminaires
- No individual controls

Installation 2: Best practice

- Regular lines of continuous direct / indirect luminaires
- Wall washers
- No individual controls

Installation 3: Best practice +

- Regular lines of continuous direct / indirect luminaires plus
 3-level switched task luminaire (CFL)
- Wall washers
- Individual control of task luminaire (hi/med/lo)

Installation 4: Best practice ++

- Regular lines of continuous direct / indirect luminaires
- Wall washers
- Individually dimmed direct / indirect lighting for each cubicle







Installation 1: Base case



Installation 3: Best practice +



Installation 2: Best practice



Installation 4: Best practice ++

Dependent variables

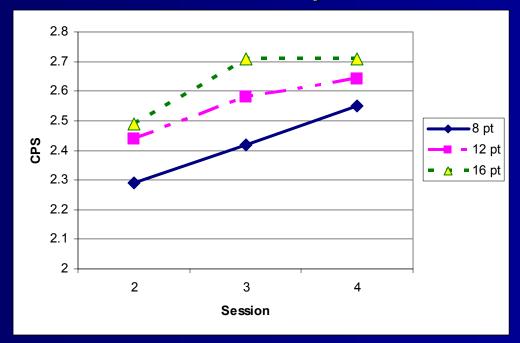
- Performance
 - Data entry
 - Text summarizing
 - Persistence on difficult "videogame" task
 - Group discussion
- Questionnaire
 - Preference, mood, overall impression on space
 - Social situations
- Vision and visual acuity measures
 - Contrast sensitivity
 - Peripheral vision/visual field size
 - Color vision
 - Near visual acuity





Results - Known Effects

- Visibility and practice Typing task (BG)
 - Large linear effects
 - Small interaction & quadratic effects

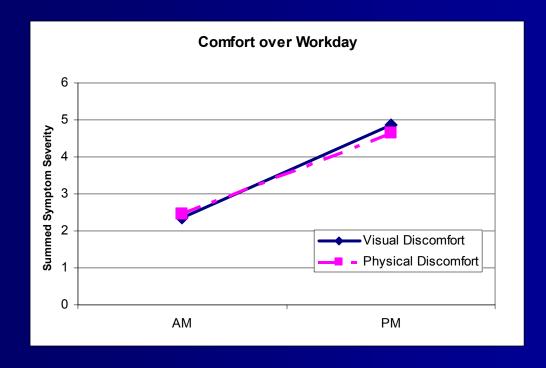






Results - Known Effects

- Fatigue Discomfort
 - Large effects of time, but low scores







Results - Appraisal

People distinguished between the 4 conditions

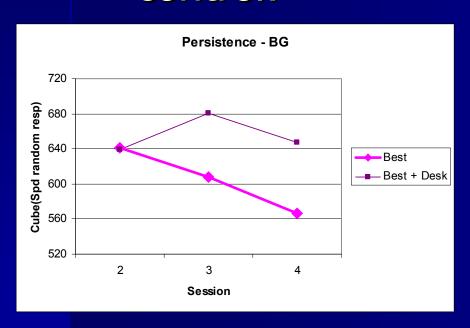
Selected Office Lighting Survey results (X test shows p<.10)	Nam(%)	BG-Afternoon	Repeaters-PM
Overall, the lighting is comfortable	69	%Agree	%Agree
Base Case		71	80
Best Practice		85	
Switching Control		81	
Dimming Control		91	96
How does the lighting compare to similar workplaces in other buildings?	19 60 22	Worse-Same-Better	Worse-Same-Better
Base Case		8 69 24	9 60 30
Best Practice		3 45 53	
Switching Control		9 52 39	
Dimming Control		7 43 50	0 50 50

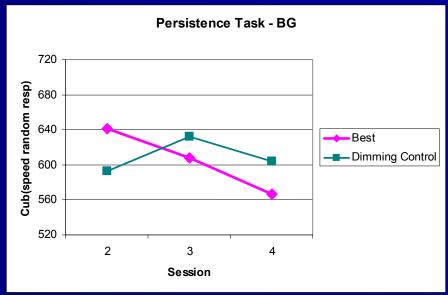




Results - Control

Several effects show benefits of control:









Acknowledgements

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Thank you!

Any questions?



